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STUDY THE CORROSION INHIBITION OF UREA FERTILIZER –Sn^{+2} FORMULATION ON REINFORCED STEEL IN SIMULATED CONCRETE PORE SOLUTION CONTAINING SODIUM CHLORIDE COMPARING WITH UREA FERTILIZER – Zn^{+2} SYSTEM

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ABSTRACT

Combination of urea-Sn^{+2} in SCP solution was examined as a corrosion inhibitor for concrete reinforced steel by potentiodynamicpolarization, surface synergist parameter and cyclic voltammetry methods comparing with urea–Zn^{+2} combination. A synergism parameter (SI) indicated a synergistic effect between urea and $Sn^{+2}$was exist. Polarization study revealed that formulation consisting of 300 ppm urea+50 ppm Sn^{+2} in SCP solution provided inhibition efficiency (IF) of 85.93% while 300 ppm urea +50 ppm Zn^{+2} provided 82.3% IF**,** and this combination acts as anodic type inhibitor. Cyclic voltammetry curves showed that the steel samples immersed in this formulation has low tendency to pitting corrosion. From these results it can be concluded that urea – Sn^{+2} inhibitor formulation is a good corrosion n inhibitor for concrete reinforced steel, it can maintain stable passive film on steel surface even in the presence of aggressive chloride ions so it can be used instead of the high toxicityZn^{+2} inhibitor to improve the corrosion inhibition of urea fertilizer inhibitor.

Keywords: Concrete Reinforced Steel, Corrosion Inhibitor, urea, synergistic effect, PotentioDynamic Polarization, Simulated Concrete Pore Solution (SCP). Cyclic voltammetry

1. INTRODUCTION

Billions of dollars are spent each year to repair the damages resulting from concrete reinforcing steel corrosion that initiates when aggressive chlorides ions, water and air penetrate through the pores solution of concrete and reach the surface of the steel. [1-5]

The use of inhibitors is one of the most important methods of protecting concrete rebar against corrosion. Corrosion inhibitors are chemical substances which can prevent or reduce corrosion rate when present in adequate amounts. [2-17]

Corrosion inhibitors have been considered as one of the most cost-effective and applicable solution to prevent concrete reinforcement corrosion. Inhibitors have the effect of reducing the oxidation and or reduction reactions on the surface of the reinforcement and also promoting a passive layer at the steel surface, which makes it more difficult for the chloride ions to remove electrons and destroying the protective film that formed on steel surface [17, 18].

Many inhibitors alone have low inhibition efficiency but the efficiency increase if it combines with other inhibitors, this occur due to the synergistic effect existing between the inhibitors [19-25] .ZnO has been used as a corrosion inhibitor [26]. Many authors investigated the synergistic corrosion inhibition of Zn^{2+} ion with other co inhibitors [27- 35].

Urea fertilizer of certain concentration was reported to be a good corrosion inhibitor for concrete reinforced steel immersed in 3% NaCl (86.5% IF at 0.5 % concentration) [36].Due to the low inhibition ability of urea at low concentration ,it is not feasible to use it alone as corrosion inhibitor . Urea in presence of Zn^{+2} ion has been examined as good corrosion inhibitor reduce the corrosion of concrete reinforced steel due to the synergistic effect between urea and Zn^{2+} ion [37] but due to the high toxicity of Zn^{+2} there is a need to reduce Zn^{+2} concentration or to replace it by another low or no toxic inhibitor[22] .Tin and tin salts (Sn^{+2}) is low toxic eco friendly material has wide applications in food industry[38] so it was used in this study to improve the inhibition efficiency of urea inhibitor instead of toxic Zn^{+2} . K.K. Sagoe – Krentsil et al [39] found that sn^{+2} at concentration of 200 mM/L is an effective inhibitor to corrosion of mild steel embedded in cement paste , but it cannot be use alone as corrosion inhibitor due to its low solubility in pore solution .

The present study evaluates the corrosion inhibition of Urea- Sn^{+2} formulation for concrete reinforced steel in simulated chloride contaminated concrete pore solution (SCP), using potentiodynamic polarization technique, surface synergism parameter and cyclic voltammetry method comparing with urea- Zn^{+2} formulation .

2. EXPERIMANTAL WORKS

2.1 Specimens preparation

Concrete reinforcement steel bar was purchased from local market. Discs of 10 mm diameter were cuts from the steel bar , grinded gradually with SiC paper from grade 80 to grade 2000 till mirror finish , then degreased by acetone , rinsed with distilled water , dried and immersed in test solutions for specified period in order to use for potentiodynamic polarization and cyclic voltammetry tests.

2.2 Solution preparation

Urea fertilizer (locally produced), analytical grade potassium hydroxide (KOH), Sodium chloride (NaCl), stannous sulfate (SnSO4) and zinc oxide (ZnO) was purchased from local supplier.
All solutions were prepared by dissolving the above chemicals in deionized water. Solution of 2% KOH and 3% NaCl was prepared to represent the chloride contaminated SCP solution (PH =13.6) In this study stannous sulfate and zinc oxide were used as synergist inhibitor to urea fertilizer inhibitor , in order to investigate the inhibition effect of each inhibitor alone 50 ppm sn^{+2} with SCP solution , 50 ppm zn^{+2} with SCP solution , 75 ppm urea with SCP solution were prepared . To investigate synergistic inhibition of sn^{+2} ion and zn^{+2} ion on urea fertilizer inhibitor , combinations of 75 ppm urea + 50 ppm sn^{+2} , 75 ppm urea + 50 ppm zn^{+2} , 300 ppm urea + 50 ppm sn^{+2} , 300 ppm urea + 50 ppm zn^{+2} were prepared also , each combination was added to the SCP solution to form the required test solution .

2.3. Electrochemical Measurements

Electrochemical measurements were carried out using potentiodynamic polarization and cyclic voltammetry technique to evaluate the inhibition effect of Urea - Sn^{+2} combination in SCP solution contaminated with corrosive NaCl solution on concrete reinforced steel comparing with urea - zn+^{2} combination . From Tafel plots corrosion rates, inhibitor efficiencies and surface synergism parameter were determined. Cyclic polarization curves were used to analyze the pitting corrosion tendencies. All tests were carried out in aerated solution at room temperature and atmospheric pressure.

2.3.1 Potentiodynamic polarization measurements

Potentiodynamic polarization technique has been used in this study to investigate the synergistic effect of Sn^{+2} ion and Zn^{+2}ion on the corrosion inhibition of urea inhibitor and to detect the formation of protective film on concrete reinforced steel surface. Three electrode cell consist of Platinum wire as a counter electrode, Ag/AgCl electrode as a reference electrode and reinforced steel specimen as a working electrode was used in this investigation. The working electrode was a flat shaped rebar steel disk of 0.785 cm^2 exposed surface area axially embedded in a Teflon holder. Wenking M Lab Potentiostat Galvanost at instrument (GERMAN origin) was used to carry out the polarization measurements under potentiodynamic conditions.

In order to investigate the synergistic effect of the inhibitors ten steel disks were immersed for one day in various test solutions. In order to verify the stability of passive film in presence of corrosive chloride ions the combination of inhibitors that showed a higher inhibition efficiency at one day immersion test was chosen to test after 7 days immersion, so one disk immersed in control solution, the second disk immersed in control solution containing 300ppm urea + 50 ppm sn^{+2} inhibitor and the third disk immersed in control solution containing 300ppm urea + 50 zn^{+2} inhibitor.

Corrosion parameters such as corrosion potential (Ecor) .corrosion current (Icor), anodic and cathodicTafel slopes (ba, bc) were evaluated by the instrument programs. Potentiodynamic polarization curves were conducted by changing the electrode potential automatically ± 200 mV around the open circuit potential at a scan rate of 1 mV/s. From Tafel plot corrosion parameters were recorded , corrosion rate (CR) and corrosion inhibition efficiency (IE %) was calculated using the following equation [40]: Corrosion rate (mmpy) = 3.2 x I_{cor} x equivalent weight / density IE % = (I_o- I) / I_o× 100 Where: Equivalent weight of steel=27.93 gm, Steel density = 7.8 gm/ cm^3, I_{cor}= current density mA/ cm2, IE = inhibition efficiency, IO and I are the corrosion current density without and with the inhibitor respectively.

2.3.2 Cyclic voltammetry measurements

Pine WaveDriver 10 Potentiostat/Galvanostat (American origin) was used to record Cyclic voltammograms of reinforced steel samples immersed in in SCP with and without inhibitors. A three-electrode cell assembly was used. The working electrode was reinforced steel disc with exposed surface area of 0.785 cm^2 .The disc surface was prepared by same procedure that was used for potentiodynamic polarization . Ag –AgCl electrode was used as reference electrode and platinum rod was used as counter electrode. Three disks were immersed in the required test solutions. The cyclic voltammetry curves were obtained from gradually increasing the potential from −1.2V to 1 V and then reversed back to −1.2 V (Ag - AgCl) with a scan rate of 50 mV/s The experiments were performed after 0.5 hr. immersion in aerated test solutions at room temperature and atmospheric pressure.

2.4. Synergism parameter

Synergism parameter (SI) are indication of synergistic effect existing between the inhibitors Synergist effect exist between the inhibitors If S_I value is more than one [22] .

The synergism parameter (SI) can be calculated from the following Relation [37]:
$S_I = 1 - \theta_{1+2} / 1 - \theta'_{1+2}$ Where $\theta_{1+2} = (\theta_1+\theta_2) - (\theta_1 \times \theta_2)$
θ_1= surface coverage of urea inhibitor in SCP solution
θ_2 = surface coverage of Sn^{+2} or Zn^{+2} inhibitor in SCP solution
θ'_{1+2}= combined surface coverage of inhibitor urea and Sn^{+2} or inhibitor urea and Zn^{+2} in SCP solution
Surface coverage = IE / 100

3. RESULTS AND DISCUSSIONS

3.1Polarization Curves

Figure 1 shows the potentiodynamic polarization curves of concrete reinforced steel samples obtained after one day immersion in the SCP solution with and without urea–zn^{+2} combinations. Corrosion current (Icor) was measured from Tafle plot, inhibitor efficiency (IF) and surface coverage (θ) was calculated from the measured Icor. All values are given in table 1. The IF of urea inhibitor increased with addition of 50 ppm zn^{+2} (from 32.2% to 78% for 75 ppm urea and from 51.1% to 87.9% for 300 ppm urea) which is an indication of the synergetic effect of Zn^{+2} inhibitor .

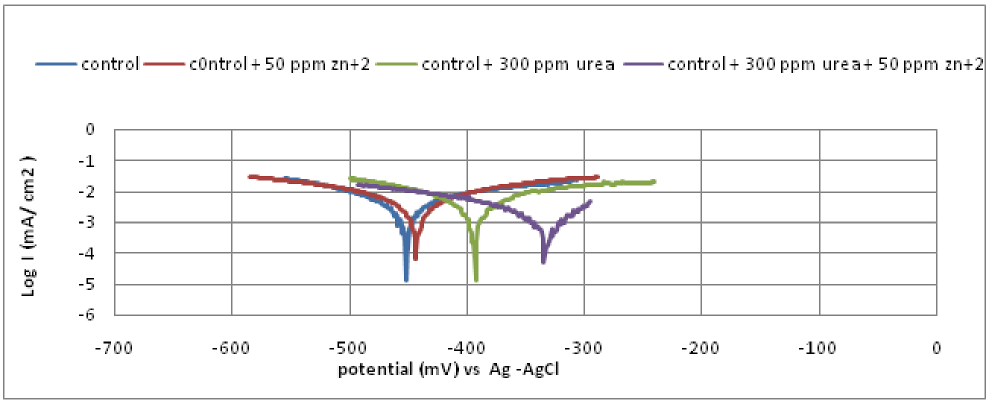

Figure 1: Electrochemical parameters of concrete reinforced steel samples studied after one day of immersion in the SCP solution without and with various concentration of urea - Zn+2 inhibitors

Table 1: Corrosion parameters obtained from polarization curves of concrete reinforced steel after one day immersion in the SCP solution without and with various concentration of urea - zn+2 inhibitor.

System	Icor $\mu A/cm^2$	IE %	Surface coverage
Control	4.191		
Control + 75 ppm urea	2.841	32.2	0.322
Control + 50 ppm zn+2	2.69	36	0.36
Control +75 ppm urea + 50 ppm zn+2	0.917	78	0.78
Control + 300 ppm urea	2.051	51.1	0.511
Control+300 ppm urea+ 50 ppm zn+2	0.55	87.9	0.879

Polarization curves of steel samples after one day immersion in SCP solution with and with out urea – sn^{+2} inhibitor are shown in figure 2. Values of corrosion parameters were tabulated in table 2. The IF of the urea inhibitor also increased with the addition of 50 ppm Sn^{+2} inhibitor (from 32.2% to 74.25% at 75 ppm urea concentration and from 51.1& to 77.8% at 300 ppm urea concentration) which indicate that Sn^{+2} inhibitor has synergistic effect on urea inhibitor

approximately the same effect of Zn^{+2} inhibitor . Corrosion current, inhibition efficiency and surface coverage, synergism parameter (SI) that calculated from polarization curves are given in table 3.

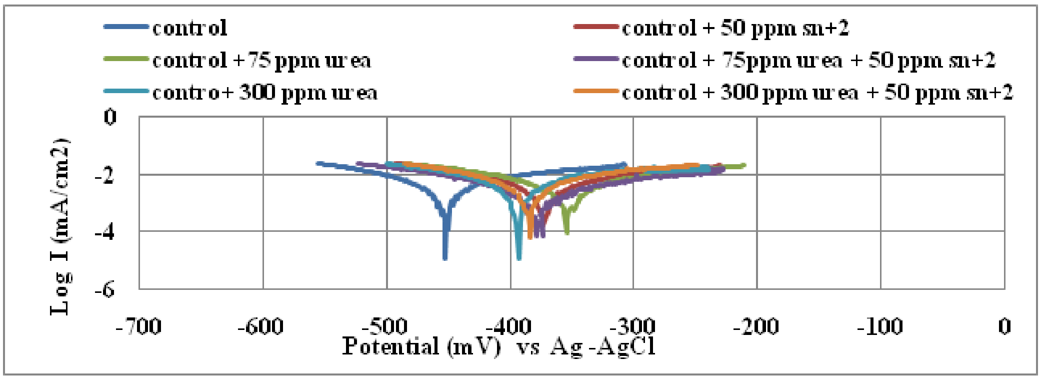

Figure 2: Electrochemical parameters of concrete reinforced steel samples studied after one day of immersion in the SCP solution without and with various concentration of urea - Sn+2 inhibitors

Table 2: Corrosion parameters obtained from polarization curves of concrete reinforced steel after one day immersion in the SCP solution without and with various concentration of urea - Sn+2 inhibitor.

System	Icor µA/ cm^2	IE %	Surface coverage
Control	4.191		
Control + 75 ppm urea	2.841	32.2	0.322
Control + 50 ppm Sn+2	2.48	40.8	0.408
Control +75 ppm urea + 50 ppm Sn+2	1.079	74.25	0.7425
Control + 300 ppm urea	2.051	51.1	0.511
Control +300 ppm urea + 50 ppm Sn+2	0.93	77.8	0.778

Table 3 . Synergism parameters (SI) for concrete reinforced steel after one day immersion in the SCP solution in the absence and presence of inhibitors.

Urea – Sn^{+2} inhibitor						Urea – Zn^{+2} inhibitor				
Urea (ppm)	θ1	θ2	θ1+2	θ'1+2	SI	θ1	θ2	θ1+2	θ'1+2	SI
75	0.32	0.41	0.59	0.74	1.56	0.32	0.36	0.57	0.78	1.98
300	0.51	0.41	0.71	0.78	1.3	0.51	0.36	0.69	0.87	2.4

The potentiodynamic polarization curves of concrete reinforced steel samples immersed for 7 days in SCP solution in absence and in presence of urea – Zn^{+2} inhibitor and urea Sn^{+2} inhibitor are shown in figure 3. Corrosion parameters are given in table 4. Data of the table shows that Ecor of the sample immersed in the control solution was -397 mV vs Ag-AgCl and it was shifted to more positive direction (- 306 mV vs Ag-AgCl) with 300 ppm urea +50 ppm Zn^{+2} combination and to (- 329 mV vs Ag-AgCl) with300 ppm urea + 50 ppm Sn^{+2} combination . The Icor of the control sample was 3.27 µA/cm^2 and it was decreased to 0.58 µA/cm^2 with 300 ppm urea + 50 ppm Zn^{+2} system and to 0.46 µA/cm^2 with300 ppm urea +50ppm Sn^{+2} system . This indicates that the protective passive film is formed on the steel surface in presence of inhibitors [35] and this will increase the life expectancy of concrete reinforced steel by more than 10-15 years in presence of urea – Sn^{+2} inhibitor [41].

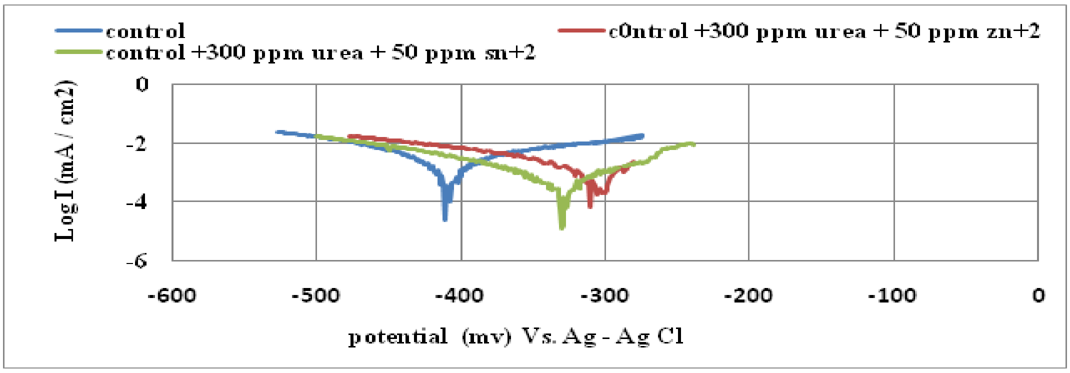

Figure 3: Electrochemical parameters of concrete reinforced steel samples studied after 7 days of immersion in the SCP solution without and with various concentration of urea and Zn+2 inhibitors

Table 4: Corrosion parameters obtained from polarization curve of concrete reinforced steel after 7 days immersion in the SCP solution without and with 300 ppm urea + 50 ppm zn+2 inhibitor and with 300 ppm urea + 50 ppm sn+2 inhibitor.

System	Ecor mV	Icor µA/ cm^2	ba mV/dec	- bc mV/dec	CR Mmpy	IE %
Control	-397.4	3.27	243.5	148.9	38.3×10^{-3}	
Control + 300 ppm urea+50 ppm sn+2	- 329.7	0.46	77.7	83.7	5.39×10^{-3}	85.93
Control +300 ppm urea + 50 ppm zn+2	-306.1	0.58	47.2	58.8	6.79×10^{-3}	82.3

According to the data of the table both the anodic and cathodicTafle constants (ba ,bc) are decreased in the presence of inhibitors , a decrease of 165.8 mV in anodic Tafle slope is much higher than 65.2 mV in the cathodicTafle slope for the 300 ppm urea + 50 ppm Sn^{+2} formulation in SCP solution and a shift of 196.3 mV in anodic slope also is much higher as compared with 90.1 mV in cathodic slope for the 300 ppm urea +50 ppm Zn^{+2} formulation in SCP solution, these results suggests that urea - sn^{+2} and urea - zn^{+2} inhibitor combinations act as anodic type inhibitor controls the anodic reaction predominantly preventing the dissolution of the metal by forming urea – Fe^{+2} complex at anodic site of steel surface and to some extent controls the cathodic reaction by forming $Sn(OH)_2$ or $Zn(OH)_2$ on the cathodic site[37] . Thus the protective film formed on steel surface consist from urea–Sn^{+2} or urea–Zn^{+2} complex and $Sn(OH)_2$ or $Zn(OH)_2$.

Urea- Zn^{+2} inhibitor formulation decreased corrosion rate from 38.3×10^{-3}mmpy of control sample to 6.79×10^{-3}mmpy with 82.3% IF and urea – Sn+2 inhibitor formulation decreased the corrosion rate to 5.39×10^{-3}mmpy with 85 .93% IF . From these results it can be concluded thaturea – Sn^{+2} inhibitor formulation is able to be good corrosion inhibitor for concrete reinforced steel instead of the high toxic urea - Zn^{+2} inhibitor formulation and it can maintain stable passive film on steel surface even in the presence of aggressive chloride ions.

3.2 Synergism parameter

The values of synergism parameters (SI) that calculated from the surface coverage are shown in table 3. It is clear from the table that the values of SI are more than one suggesting that synergistic effect exist between urea and Sn+2 and between urea and Zn^{+2} inhibitor .

3.3 cyclic voltammetry

As mentioned earlier the cyclic voltammetry in this study was used to investigate the tendency of reinforced steel to pitting corrosion. Many researchers reported that the size of hysteresis loop is an indication of tendency of metals to pit , The larger the hysteresis loop, the higher tendency to pit and the more difficult to repassivation , the smaller loop ,the lesser the tendency to pit and

easier to repassivate the pit if it occurred [42]. Figures 4, 5, 6 show the cyclic polarization curves of concrete rebar samples immersed 0.5 hour in SCP solution with and without inhibitor. large hysteresis loop for the control sample was observed which illustrates the greater tendency to pit .The hysteresis loop of sample immersed in urea - Zn^{+2} system and urea – Sn^{+2} system was approximately equal and lesser than that for control sample . This suggest that the pitting tendency of reinforced steel became less and repassivation of the pit became easier with addition the above mentioned inhibitors.

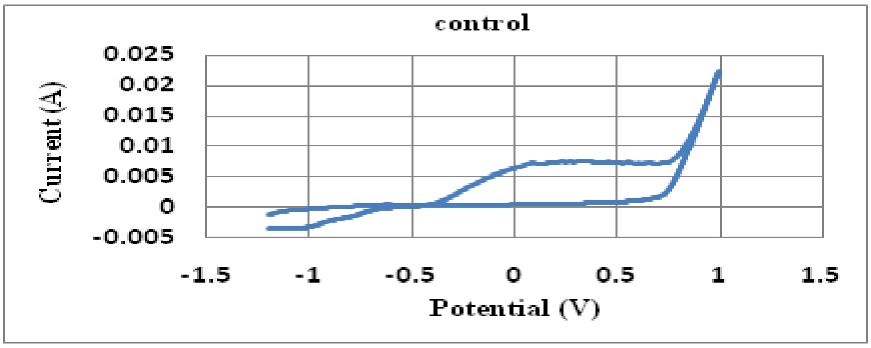

Figure 4: Cyclic voltammogram obtained from immersion of concrete reinforced steel sample 0.5 hr. in SCP solution without inhibitor (control sample)

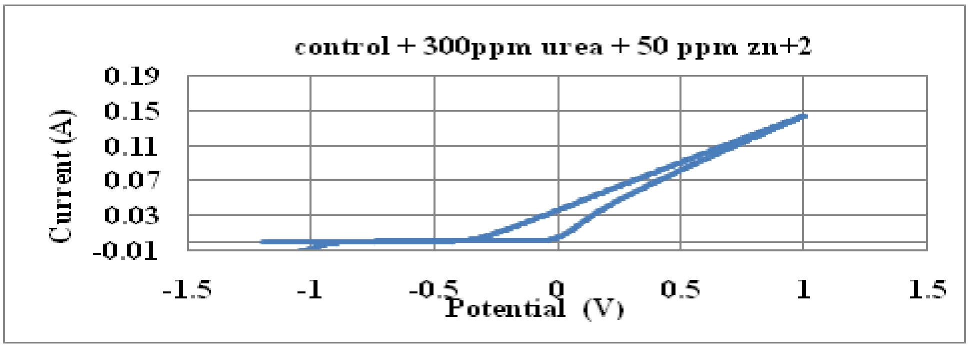

Figure 5: Cyclic voltammogram obtained from immersion of concrete reinforced steel sample 0.5 hr. in SCP solution containing 300ppm urea + 50 ppm Zn^{+2} inhibitor

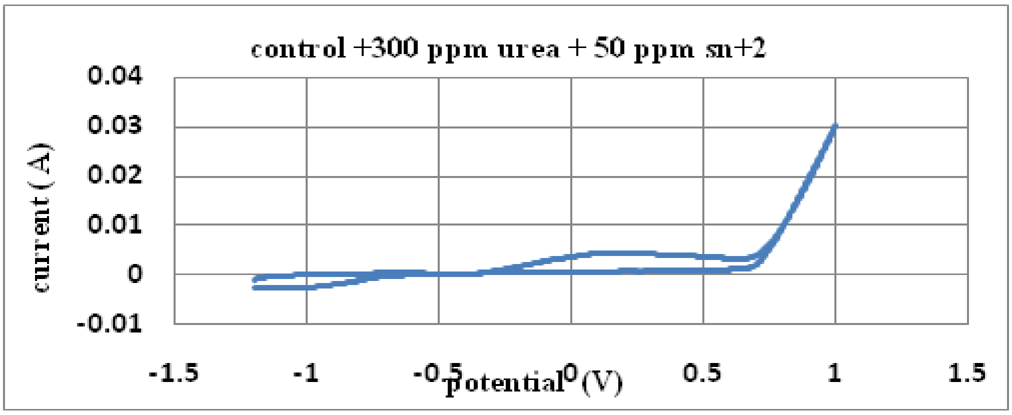

Figure 6: Cyclic polarization plots obtained after one day immersion of concrete reinforced steel samples in SCP solutions containing 33ppm urea +50 ppm Sn^{+2}inhibitor

4. CONCLUSION

Polarization study of the one day immersion of reinforced steel in test solutions indicated the synergistic effect of Sn^{+2} ion on the urea inhibitor. Polarization study of the 7 days of immersion indicated that the 300 ppm urea + 50 ppm Sn^{+2} formulation has maintained a stable passivation layer which protect the steel reinforcement from the corrosive environment. The 300 ppm urea + 50 ppm Sn^{+2} formulation inhibitor in SCP solution has successfully inhibited corrosion of the rebar in a 3% NaCl solution during the time of this study with 85.93% IF which suggest the ability to replace Sn^{+2} ion instead of Zn^{+2} ion in improving urea inhibitor corrosion efficiency. The life expectancy of concrete reinforced steel will increase by more than 10-15 years in presence of urea – Sn^{+2}inhibitor.

REFERENCES

[1] Bavarian B., Reiner L. (March 2002), "Corrosion Protection of Steel Rebar in Concrete using Migrating Corrosion Inhibitors", MCI 2021 & 2022", Prepared for: The Cortec Corporation, California State University, Northridge.

[2] Tang Y., Zhang G. and Zuo V. (2012)." Inhibition effects of several inhibitors on rebar in acidified concrete pore solution.", Construction and Building Materials. 28: 327-332.

[3] Tang Y., Zhang G. and Zuo V. (2012) "Inhibition effects of several inhibitors on rebar in acidified concrete pore solution". Construction and Building Materials.28: 327-332.

[4] Nguyen T.N., B, Hubbard J and McFadden G.B. (1991)"Mathematical model for the cathodic blistering of organic coatings on steel immersed in electrolytes". International Journal Coating Technology. 63: 43-52.

[5] Noor E.A., (2008) "Comparative study of corrosion inhibition of mild steel by aqeous extract of fenugreek seeds and leaves in acidic solution". Journal of Engineering and Applied sciences 3(1), 23-30

[6] Ebenso E.E., and et al (2009)," Inhibition of the corrosion of mild steel by Methocarbamol". Portugaliae Electrochimica. Acta.27 (1), 13-22.

[7] Ebenso E.E. and et al (2008)" Corrosion inhibitive properties and adsorption behaviour of ethanol extract of Piper guinensis as a green corrosion inhibitor for mild steel in H2S04". Afri. J. Pure Appl. Chem. 4(11), 107-115.

[8] Oguzie, E.E. (2006),"Adsorption and corrosion inhibitive properties of Azadirachtaindica in acid solutions" Pigment Resin Technol. 35(6),334-340.

[9] Gazquez J.L. (2006)," Quantum chemical study of the inhibitive properties ofn2-pyridyl-azoles". J. Phy.Chem. 110, 8928- 8934.

[10] Breslin C.B. and Geary M. (1998),"The Influence of Rare Earth Metal Passivation Treatments on the Dissolution of Sn/Zn Coatings" Corrosion 54 964CrossRef.

[11] Shreir L. L. et al (1994) ," Corrosion Metal Environment Reaction" vol 1 pp 4–160.

[12] Fontana M.G. and Greene N.D. (1982)"Corrosion Engineering".(2nd Ed.) McGraw-Hill.Inc.

[13] Parameswari K. et al (2012), "Investigation of Benzothiazole Derivatives as Corrosion Inhibitors for Mild Steel", PortugaliaeElectrochimica, 30(2), 89-98.

[14] Benabdellah M. et al (2006)"Investigation of the inhibitive effect of triphenyltin 2-thiophene carboxylate on corrosion of steel in 2 M H3PO4 solutions". Appl. Surf. Sci. 252, 8341-8347.

[15] Noor E.A.(2005),"The inhibition of mild steel corrosion in phosphoric acid solutions by some N-heterocyclic compounds in the salt form". Corrosion Sci. 47,33-55.

[16] Fiala A. et al (2007), "Investigations of the inhibition of copper corrosion in nitric acid solutions by ketene dithioacetal derivatives". Appl. Surf. Sci. 253 9347–9356.

[17] Michael M. and Sprinkel, P.E. (June 2003), "Evaluation of corrosion inhibitors for concrete bridge deck patches and over lays report", Virginia Transportation Research Council.

[18] Knoll H. (Nov. 2002) , "NRC studies corrosion inhibitors for reinforcing steel in concrete", , The Ottawa Construction News, v. 12, no. 11, , p. 8-18.

[19] Tang L., and et al "Synergistic effect between 4-(2-pyridylazo) resorcin and chloride ion on the corrosion of cold rolled steel in 1.0 M phosphoric acid". Appl. Surf. Sci. 253, 2367–2372.

[20]. Li X., Tang L. (2005), "Synergistic inhibition between OP and NaCl on the corrosion of cold-rolled steel in phosphoric acid". Mate. Chem. Phys. 90, 286- 297.

[21] Mu G., Li X., Li F. (2004),"Synergistic inhibition between o-phenanthroline and chloride ion on cold rolled steel corrosion in phosphoric acid". Mate. Chem. Phys. 86, 59-68.

[22] S. AgnesiaKanimozhi, S. Rajendran (2009),” Inhibitive Properties of Sodium tungstate-Zn2+ System and its Synergism with HEDP”, Int. J. Electrochem. Sci., 4 , 353 - 368

[23] Jiajian C. and Xiaoming W. (1990),"Proceedings of Seventh European Symposium on Corrosion Inhibitors", Ferrara, Italy, (9) 1049-1054.

[24] Sherine H.B. (sep.2012), "Inhibition of corrosion of mild steel in well water by phenolic compounds", Thesis submitted to the Bharathidasan University for the award of the degree of PhD in chemistry

[25] AppaRao B. V., and etl (2010) ," Tungstate as a synergist to phosphonate-based formulation for corrosion control of carbon steel in nearly neutral aqueous environment". J ChemSci 122:639-649.

[26] OladisTroconis de Rincon et al (2002) ,” Long-term performance of ZnO as a rebar corrosion inhibitor”, Cem. & Conc. Comp. 24, 79-87.

[27] AppaRao B V, and etl (2013), “N, N-bis (phosphonomethyl) glycine, Zn^{2+} and tartrate” – A new ternary inhibitor formulation for corrosion control of carbon steel". Int J Mater Chem 3:17-27.

[28] AppaRao B V,andetl (2005),"Synergistic effect of NTMP, Zn2+ and ascorbate in corrosion inhibition of carbon steel". Indian J ChemTechnol 12:629-634.

[29] S. Rajendran et al (2002), “The Role of Phosphonates as Transporters of Zn2+Ions in the Inhibition of Carbon Steel in Neutral Solutions Containing Chlorides”, Anti-Corrosion Methods and Materials, 49, 205.

[30] S. Rajendran et al (2000), “Corrosion Inhibition by Phosphonic Acid -Zn2+Systems for Mild Steel in Chloride Medium”, Anti-Corrosion Methods and Materials, 47, 359.

[31] R.Epshiba et al (2014) ,” Inhibition Of Corrosion Of Carbon Steel In A Well Water By Sodium Molybdate – Zn2+ System” Int. J. Nano. Corr. Sci. Engg. 1(1) (2014) ,pp 1-11

[32] C. Mary Anbarasi et al (2012) ,” Corrosion Inhibition by an Ion Pair Reagent-Zn2+ System” . The Open Corrosion Journal, 5, 1-7

[33] A. Sahaya Raja et al (2013) ,” Inhibition of Corrosion of Carbon Steel in Well Water by DL-Phenylalanine-Zn2+ System “, Hindawi Publishing Corporation , Journal of Chemistry Vol. 2013, Article ID 720965, pp 1-6

[34] Benita Sherine et al (2010), “Inhibitive action of hydroquinone - Zn2+system in controlling the corrosion of carbon steel in well water “, International Journal of Engineering Science and Technology Vol. 2(4), 341-357

[35] Pandiarajan M. et al (2014) ,”Corrosion Inhibition by Potassium Chromate-Zn2+ System for Mild Steel in Simulated Concrete Pore Solution” Res. J. Chem. Sci.,Vol. 4(2), 49-55

[36] AbdulrasoulSalih Mahdi (2014) , “Urea Fertilizer as Corrosion Inhibitor for Reinforced Steel in Simulated Chloride Contaminated Concrete Pore Solution”, International Journal of Advanced Research in Engineering & Technology (IJARET), Volume 5, Issue 5, pp. 30 - 39

[37] M. Manivannan et al (2011). “Investigation of Inhibitive Action of Urea – Zn+2 System in the Corrosion Control of Carbon Steel in Sea Water”, International Journal of Engineering Science and Technology (IJEST) Vol. 3 No.11, pp 8048 -8060.

[38] Steve Blunden, Tony Wallace (2003)," Review Tin in canned food: a review and understanding of occurrence and effect," Food and Chemical Toxicology 41, 1651–1662

[39] K.K. Sagoe et al (1994),"corrosion inhibitor for mild steel: stannous tin (Sn+2) in ordinary Portland cement", cerement and concrete research, vol. 24, No 2, pp, 313-314

[40] M. Ramasubramanian (2001), "Inhibition action of calcium nitrite on carbon steel rebars", Journal of Materials in Civil Engineering, January/February, 10-17

[41] Behzad Bavarian, Lisa Reiner (2003), "Corrosion Protection of Steel Rebar in Concrete with Optimal Application of Migrating Corrosion Inhibitors, MCI 2022", The Corte Corporation 4119 White Bear Parkway St Paul, MN 55110 (Report #1137).

[42] M.A. Amin et al (2010)." Inhibition of Uniform and Pitting Corrosion Processes of Al Induced by SCN- anions - Part I. Effect of Glycine", Portugaliae Electrochimica Acta, 28(2), 95-11.

[43] Abdulrasoulsalih Mahdi and Shymmakadhem Rahem, "Corrosion Inhibition of Reinforced Steel by Thymus Vulgarize (Thyme) Extract In Simulated Chloride Contaminated Concrete Pore Solution" International Journal of Civil Engineering & Technology (IJCIET), Volume 5, Issue 7, 2014, pp. 99 - 107, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.

[44] Abdulrasoul Salih Mahdi, "Amoxicillin As Green Corrosion Inhibitor For Concrete Reinforced Steel In Simulated Concrete Pore Solution Containing Chloride" International Journal of Advanced Research in Engineering & Technology (IJARET), Volume 5, Issue 6, 2014, pp. 99 - 107, ISSN Print: 0976-6480, ISSN Online: 0976-6499.

[45] Abdulrasoul Salih Mahdi, "Urea Fertilizer As Corrosion Inhibitor For Reinforced Steel In Simulated Chloride Contaminated Concrete Pore Solution" International Journal of Advanced Research in Engineering & Technology (IJARET), Volume 5, Issue 5, 2014, pp. 30 - 39, ISSN Print: 0976-6480, ISSN Online: 0976-6499.